Solid Electrolyte Chemical Sensors for Aerospace Applications

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Outline

- **Background of Chemical Sensors at NASA GRC**
- **Solid Electrolyte Chemical Microsensors**
  - Oxygen sensors
  - Carbon dioxide sensors
- **Summary**

Background of Chemical Sensors at NASA GRC

- **Sensors and platforms**

  H_2, CH_4, C_2H_4, C_3H_6, CO_2, CO, NOx, and N_2H_4
  Schottky diodes, resistors, and electrochemical cells

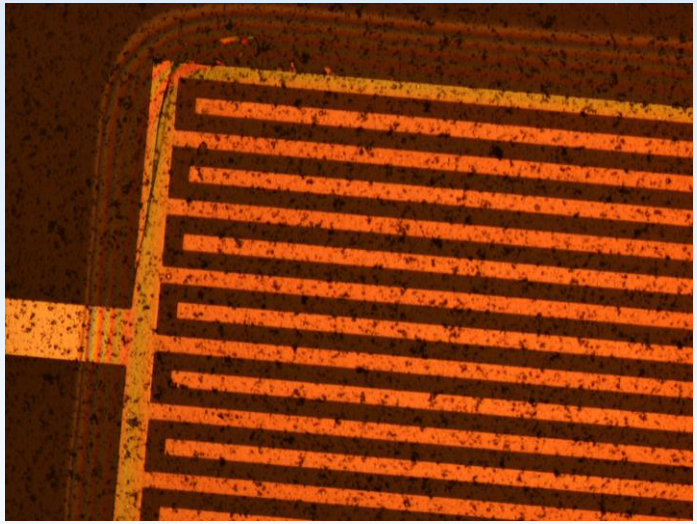
- **Approaches**

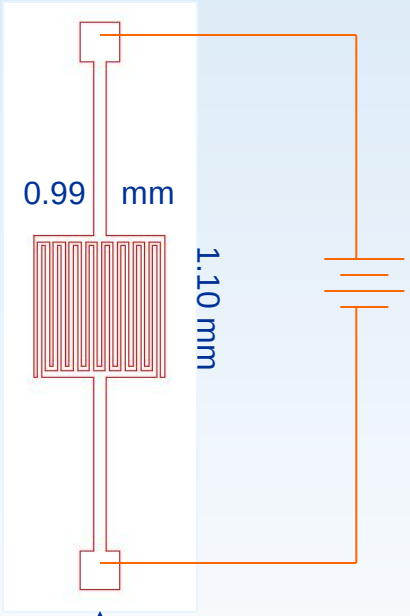
  Microfabrication, small size, low weight, cost, and power consumption. Batch fabrication, sensor arrays, smart sensor system and use as “Lick and Stick”

- **Applications**

  Engine health and emissions monitoring, fuel leak detection, low false alarm fire detection, and environmental monitoring

Oxygen Microsensor Structure

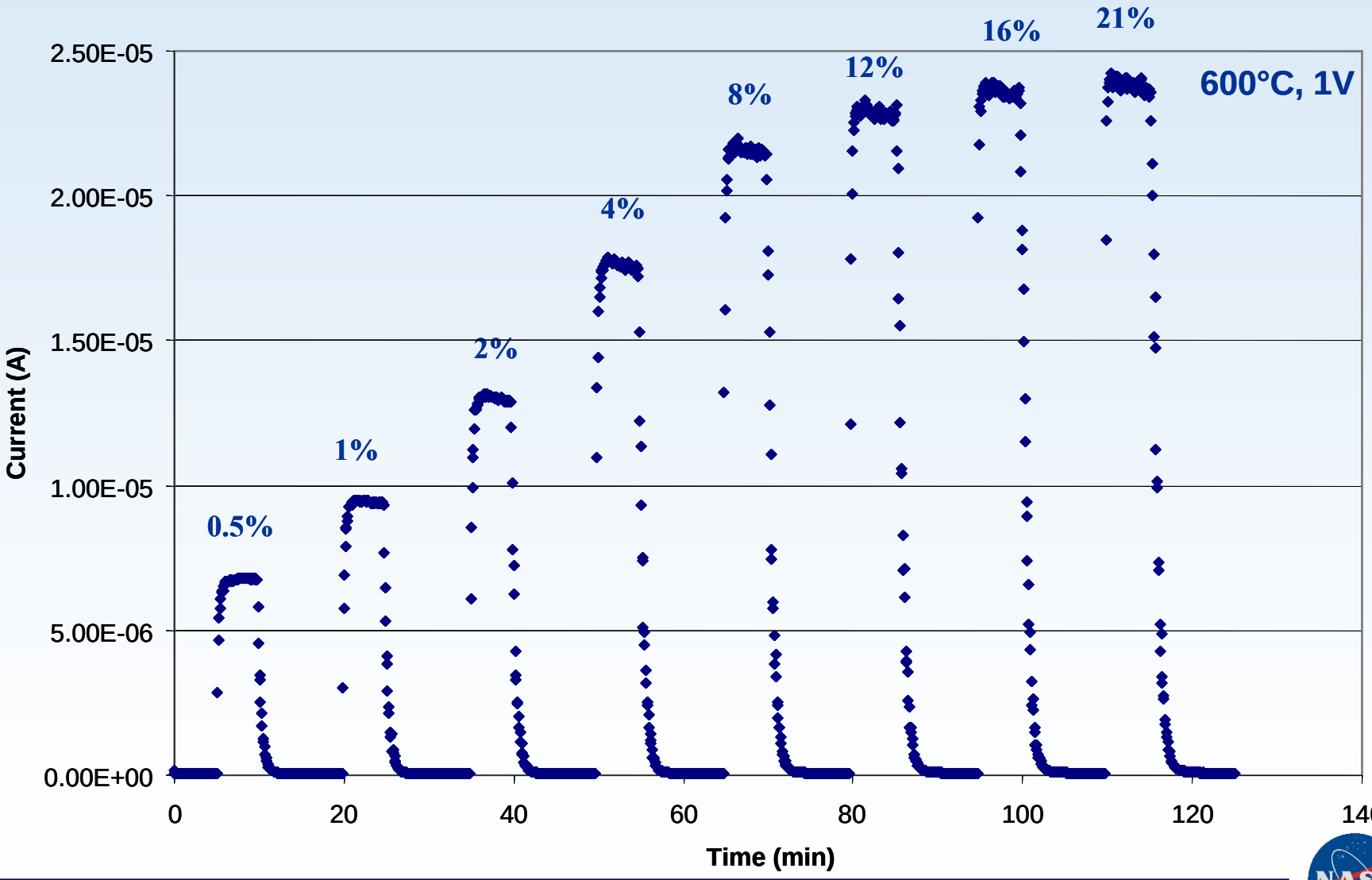




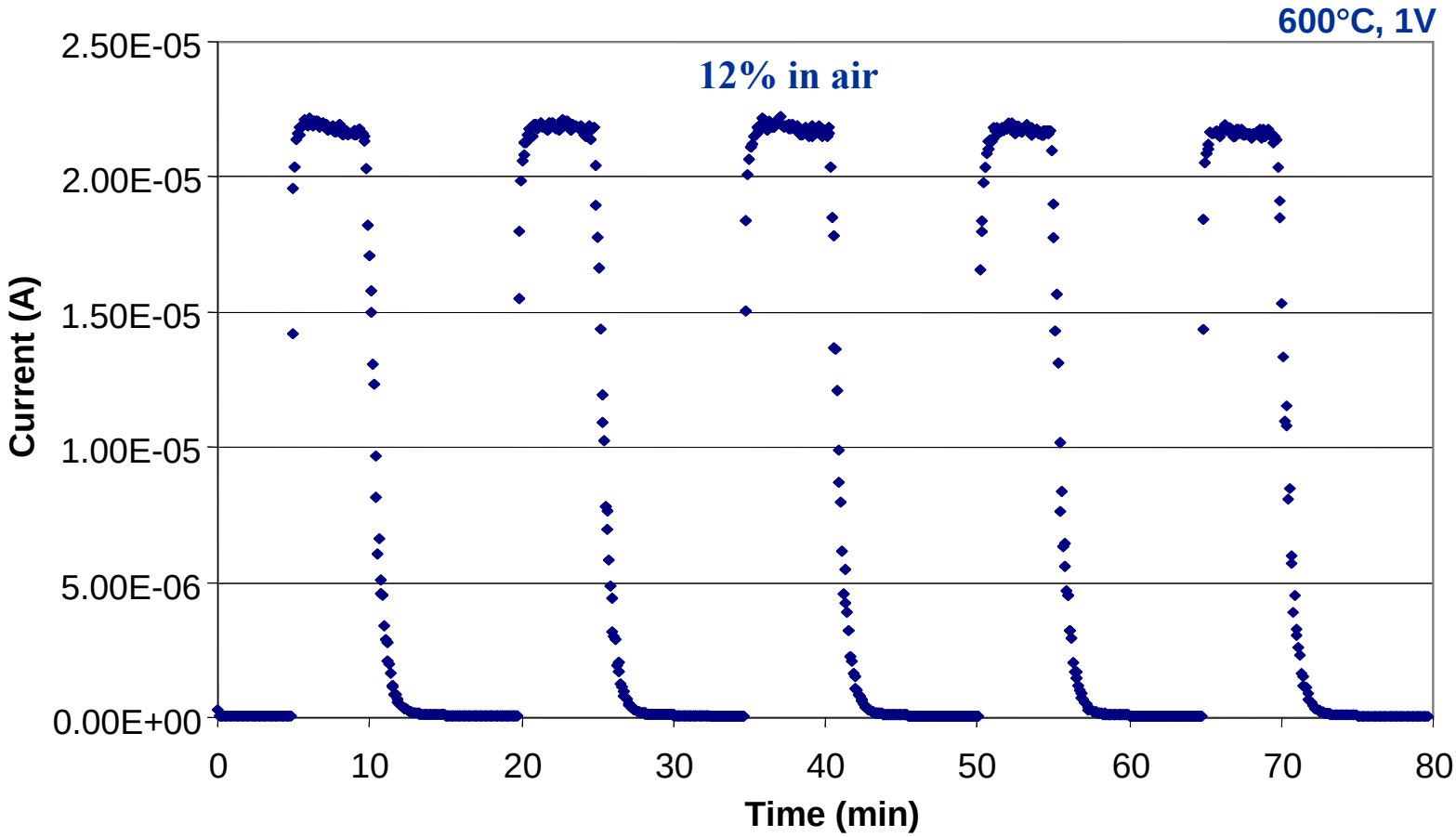
Partial Image of a fabricated oxygen microsensor. One material system: Yttria stabilized zirconia (YSZ)

AutoCAD drawing of an interdigitated electrode structure and two contacts

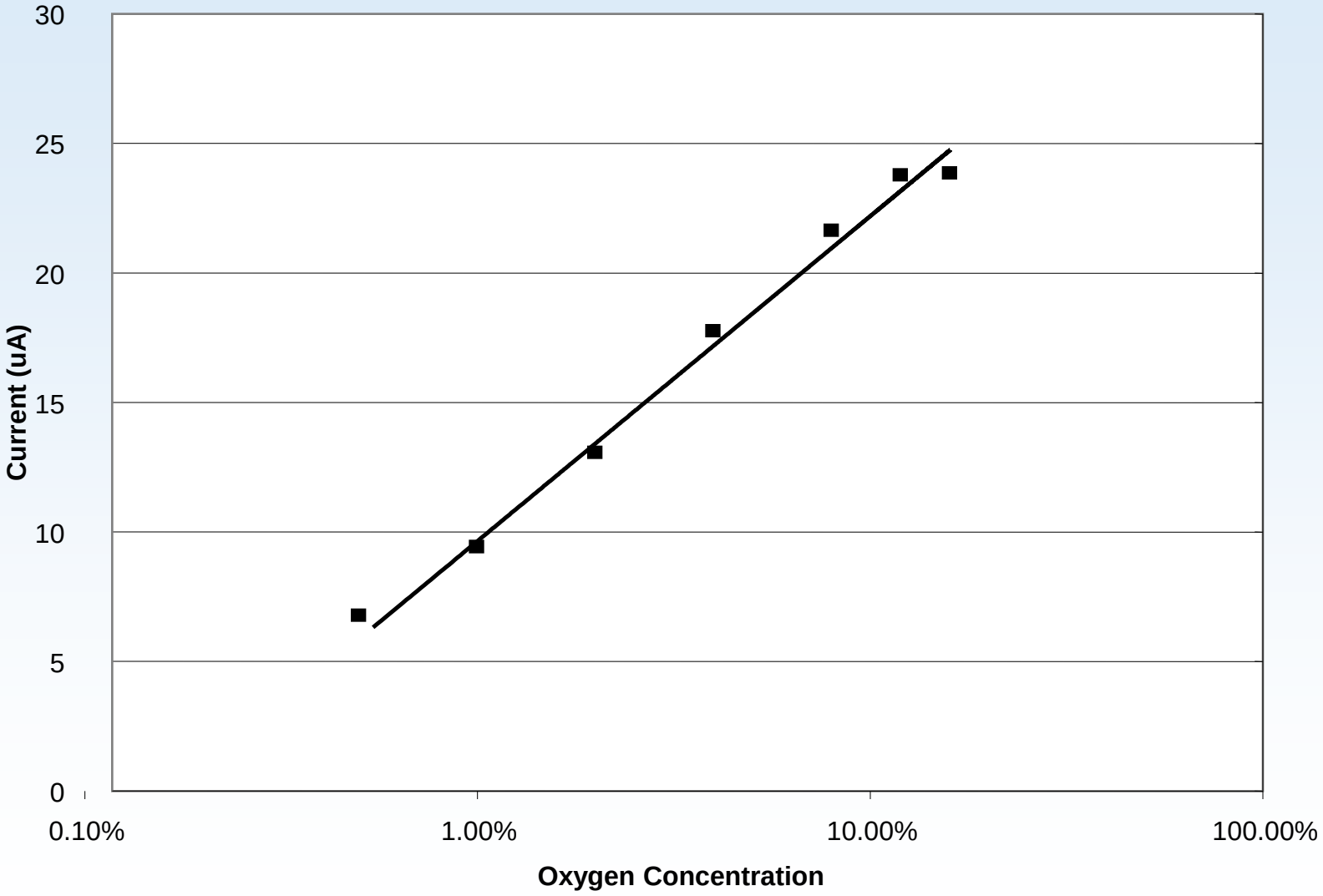
Oxygen Microsensor Testing Results



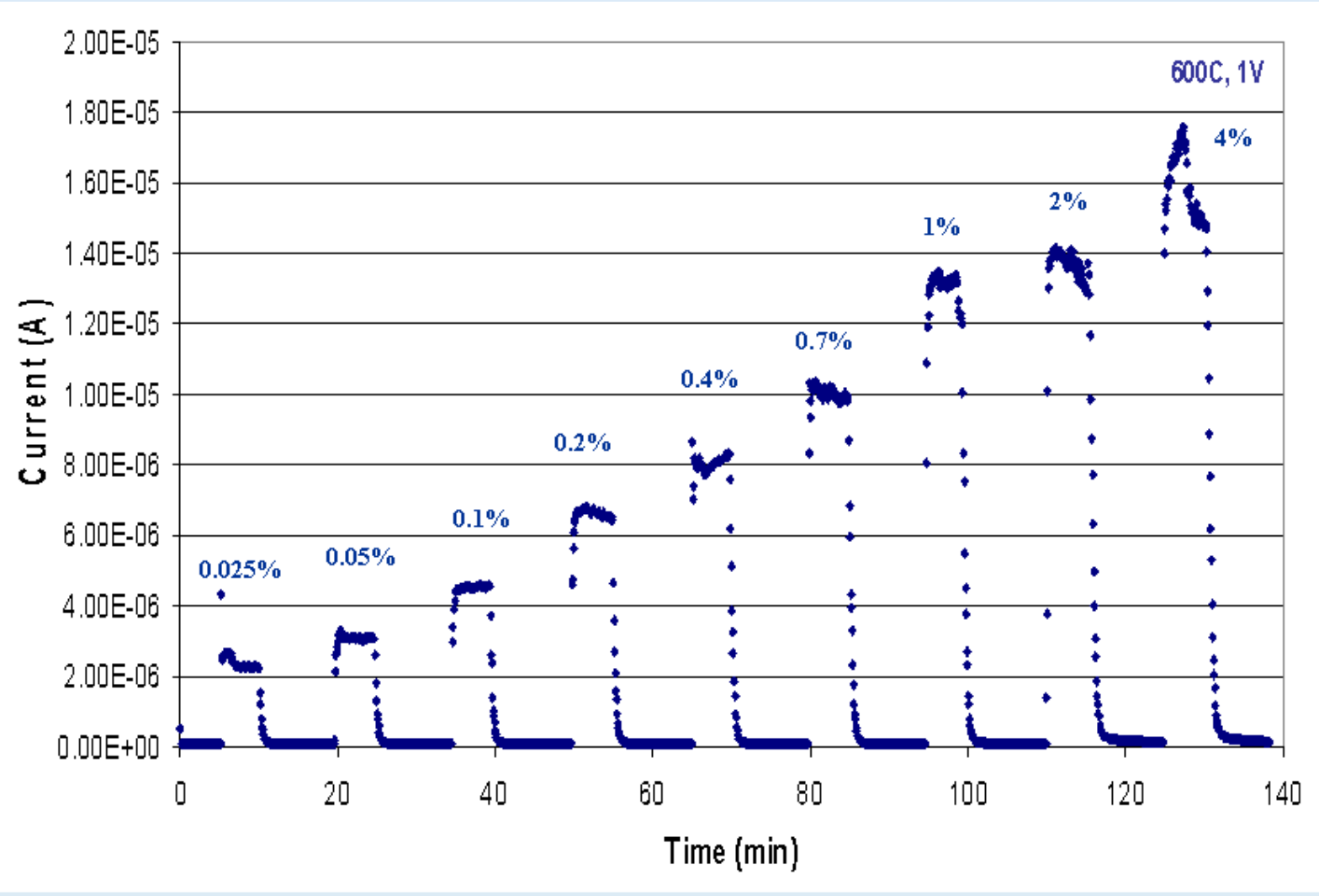
Oxygen Microsensor Repeatability Testing



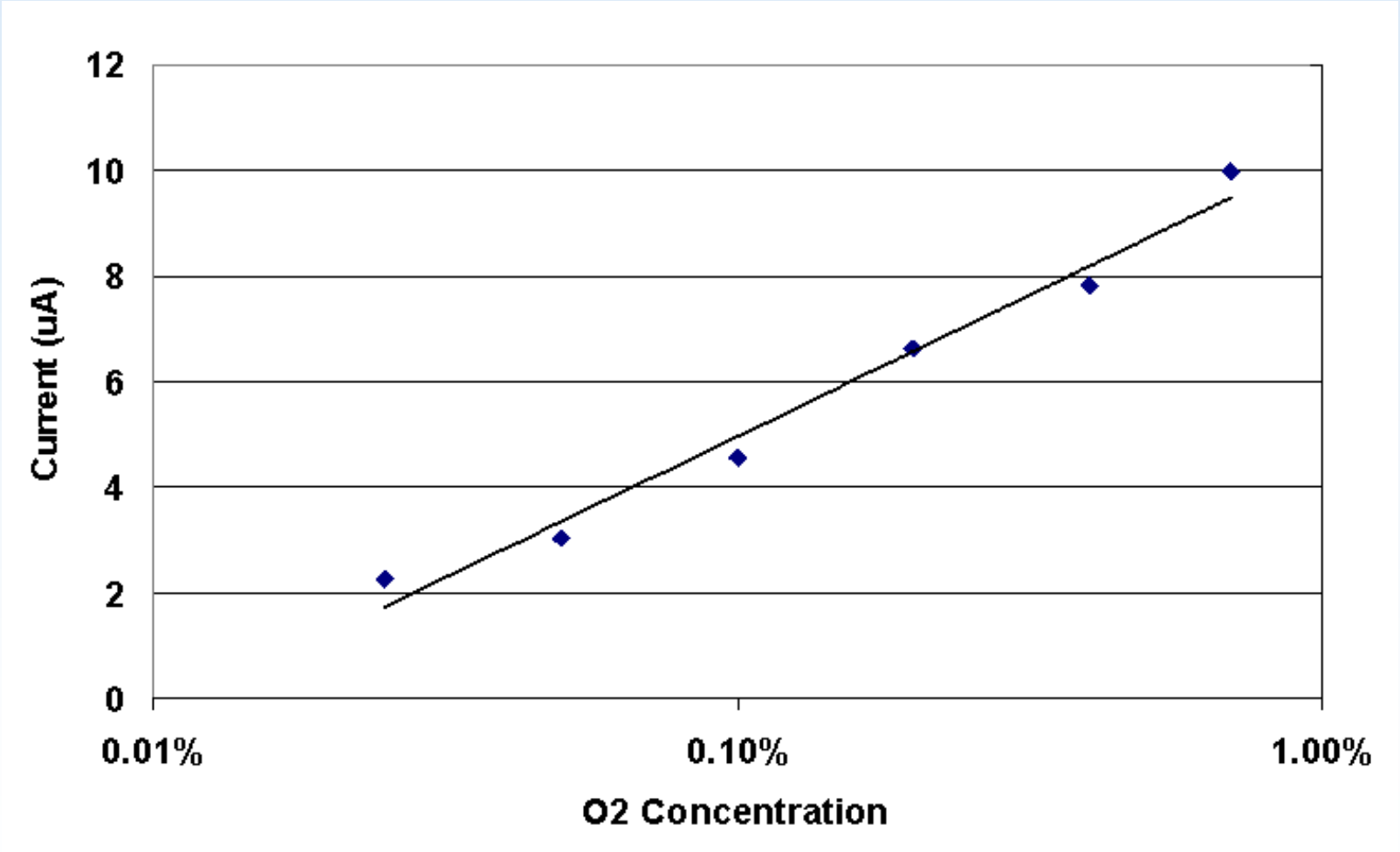
Oxygen Microsensor Current Vs. Log of Oxygen Concentration (Linear fitting from 0.5% to 16%)



Oxygen Microsensor Testing Results

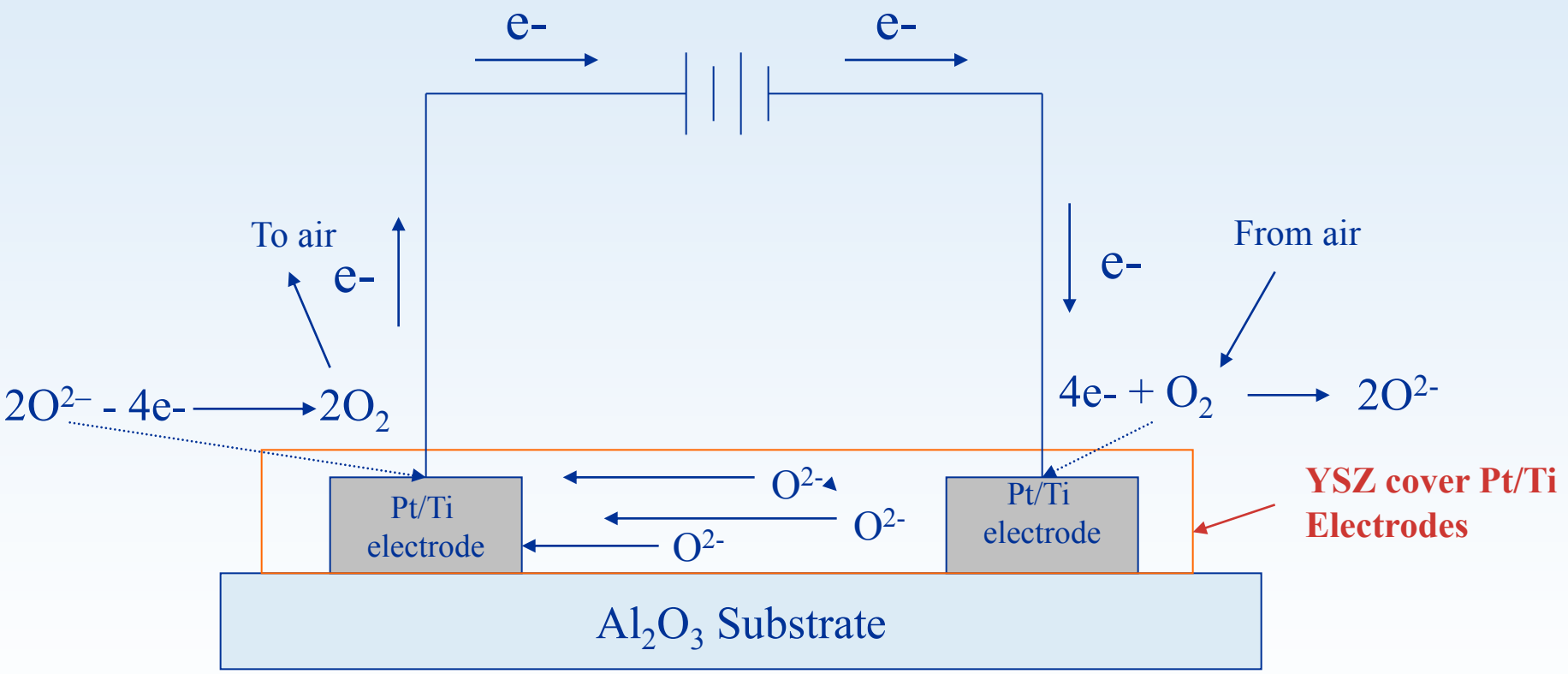


Oxygen Microsensor Current Vs. Log of Oxygen Concentrations (Linear fitting from 0.025% to 0.7%)



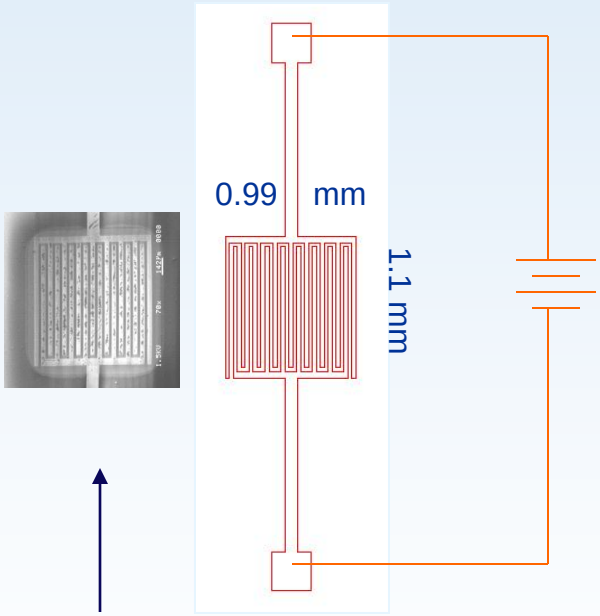
Amperometric O_2 Microsensor Sensing Mechanism

(Interdigitated electrodes simplified showing one pair of electrodes)



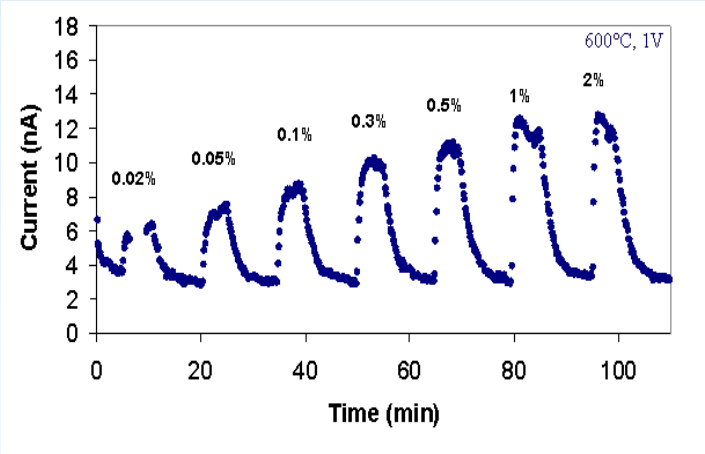
Solid Electrolyte Carbon Dioxide Microsensors

Pt interdigitated finger electrode on Al_2O_3 substrate



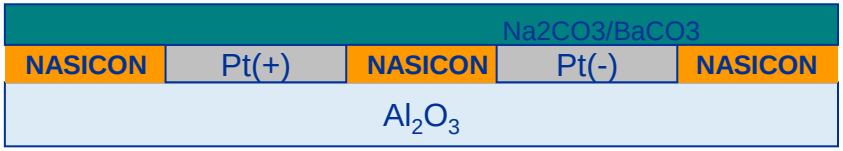
SEM image of a fabricated CO_2 sensor

Carbon dioxide microsensor tested at 600°C, 1V



Side view of microfabricated CO_2 sensor

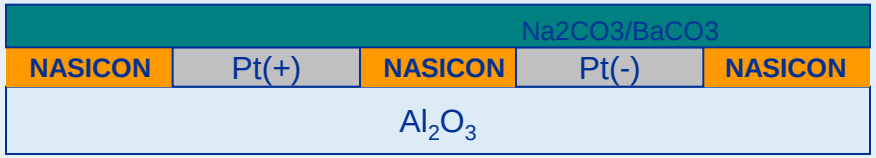
(Simplified with two electrodes, patent filed)



Nanocrystalline Tin Oxide Coated to Reduce Solid Electrolyte Carbon Dioxide Sensor Operation Temperature

Side view of microfabricated CO_2 sensor

(Simplified with two electrodes, new tech. disclosed, patent filed)



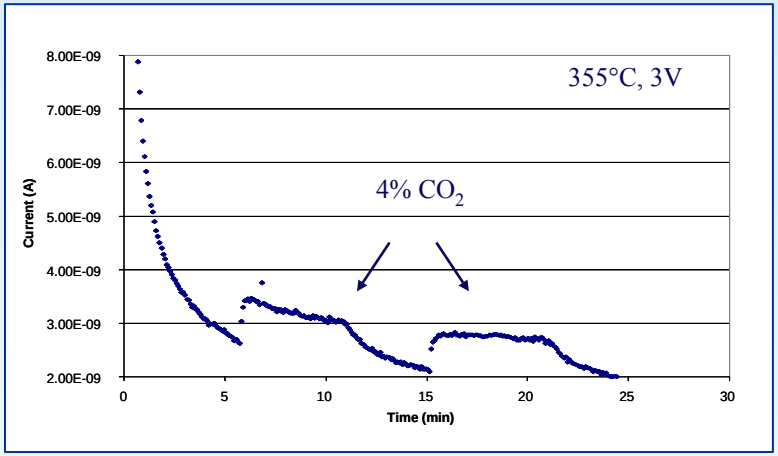
Coated with SnO_2 sol gel, heated at 500°C for 2 hr

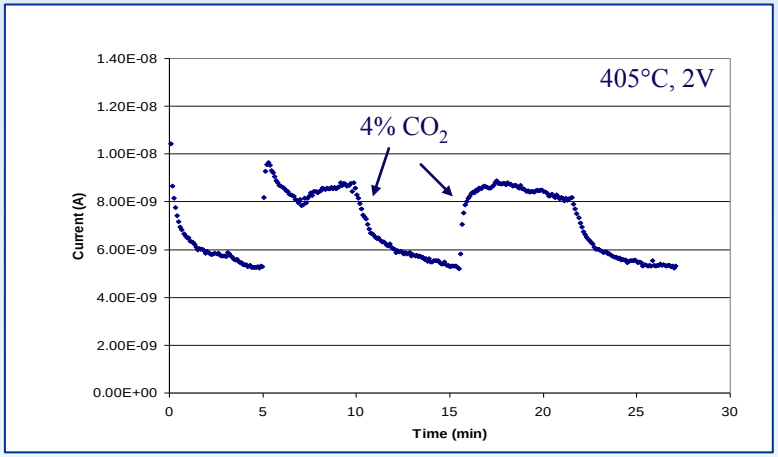
Side view of microfabricated CO2 sensor
Coated with Nanocrystalline tin oxide

Nanocrystalline Tin Oxide Improves Solid Electrolyte Carbon Dioxide Sensor Performance

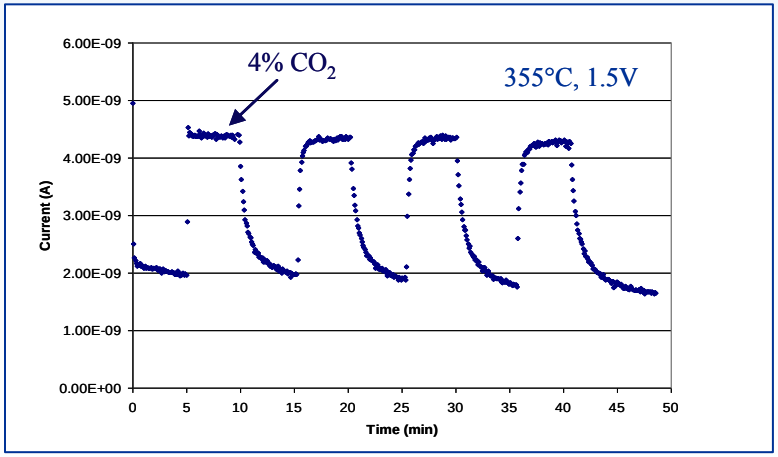
Sensor Responses Significantly Changed with Nanocrystalline Coating

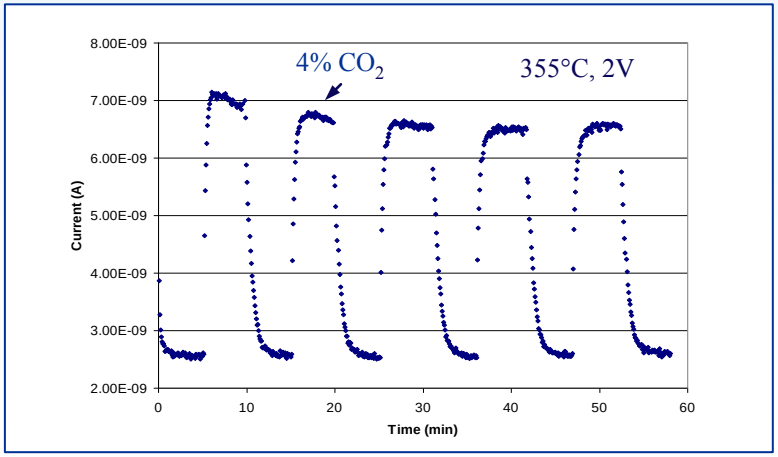
Sensors without tin oxide sol gel addition





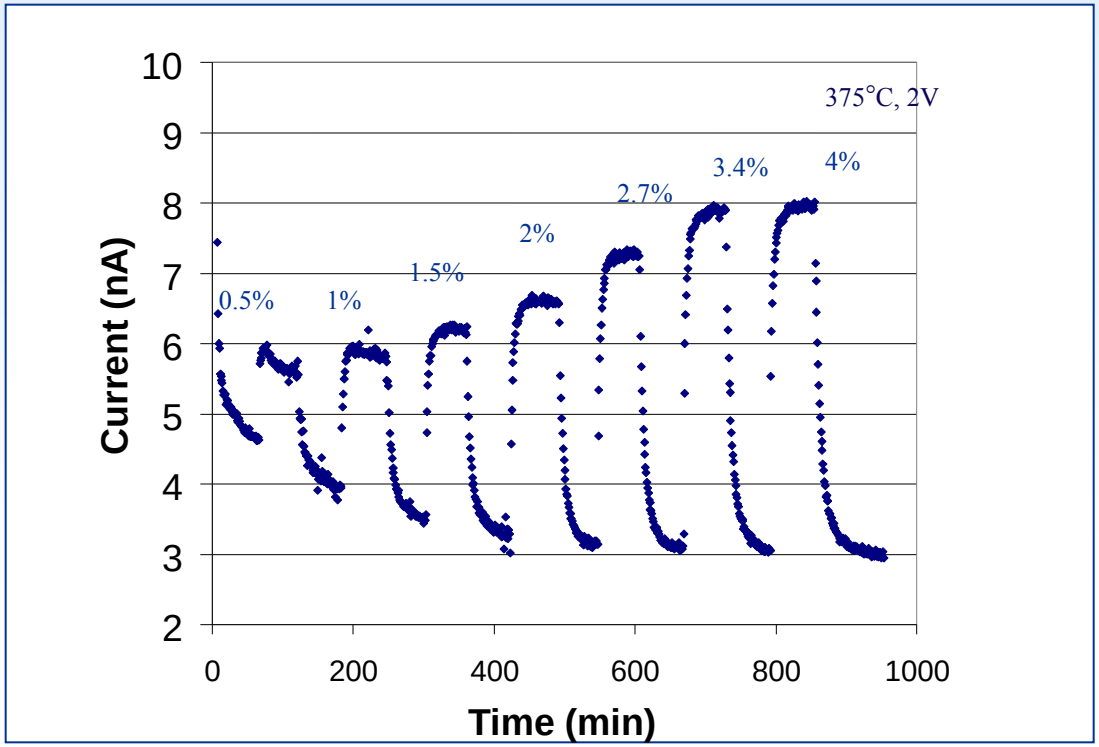
Sensors after tin oxide sol gel addition



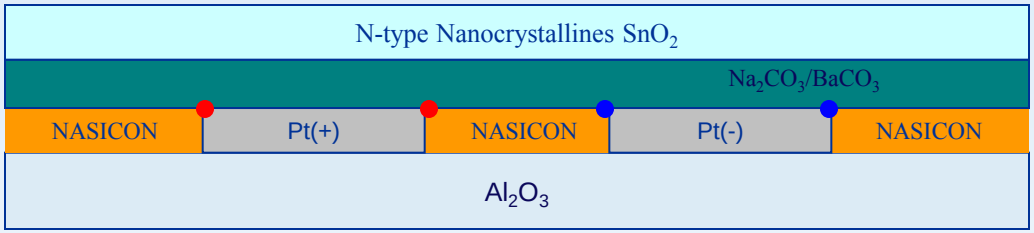


Nanocrystalline Tin Oxide Improve Solid Electrolyte Carbon Dioxide Sensor

Solid Electrolyte CO_2 Sensor with Nanocrystalline SnO_2
(Detection temperature greatly reduced from 600°C to 375°C)



Sensing Mechanism of Solid State Electrochemical Sensors for Carbon Dioxide Gases



- **Reduction site**
- **Oxidation site**

- Reduction reaction at Pt(-) electrodes

  $2Na^+ + CO_2 + 1/2\ O_2 + 2e^- \rightarrow Na_2CO_3$

- N-type metal oxides: supply more electrons or enhance electrons flow

- Results: Detection temperature decreased and power consumption reduced

Summary

- **Oxygen and carbon dioxide microsensors developed using same microsensor platform**
- **Oxygen sensor uses one sensing material system YSZ. By depositing the right thickness, YSZ can be both diffusion barrier and sensing material. Simplest sensor fabrication but wide oxygen detection was achieved: linear current response to the log of oxygen concentration from 0.025% to 16%**
- **Carbon dioxide sensor using two-material sensing system uniquely fabricated on interdigitated electrode, forming robust structure. Wide carbon dioxide detection achieved. Linear current response to the log of carbon dioxide concentration from 0.02% to 2% in air**
- **Solid electrolyte CO_2 sensor improved and sensor power consumption decreased through addition of n-type SnO_2 nanomaterial. CO_2 operation temperature decreased from 600°C to 375°C. CO_2 in air from 0.5% to 4% was tested**
- **Further improvement including expending sensor detection ranges and further reduce power consumption by reducing operation temperature.**
- **Oxygen and carbon dioxide microsensors can be used for aerospace applications such as fire detection and environmental monitoring.**

Acknowledgements

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